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Wetlands and waterbirds at Point Storkersen, Alaska

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Wetlands and waterbirds at Point Storkersen, Alaska

by

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INTRODUCTION

Aquatic habitats and waterbirds form major components of Alaska's Arctic Coastal Plain ecosystem (Kessel and Cade, 1958). Lakes and ponds cover 50 to 75 percent of the coastal plain (Black and Barksdale, 1949) and represent one of the largest and most stable collections of wetlands in North America (Wellein and Lumsden, 1964:72). Although the icefree season is short, the Coastal plain and similar arctic regions provide the principal breeding grounds for certain species of loons, geese, sea ducks, and shorebirds.

Discovery and proposed development of large oil and gas reserves in coastal plain deposits near Prudhoe Bay (Figure 1) have prompted national concern over potential environmental damage (Bartonek et al., 1971). Current development is limited primarily to the vicinity of Prudhoe Bay, but industrial activities will expand rapidly as construction of a pipeline for transporting oil progresses. Little is known about the effect of oil spills and other consequences of petroleum exploitation on arctic aquatic and terrestrial communities, but disturbances could be severe in this relatively simple ecosystem. More information concerning populations and habitats of wildlife is necessary to accurately measure the environmental impact of oil and gas development on the coastal plain and to provide recommendations to minimize damage.

This study appraises populations of water-related birds in relation to their aquatic habitats in the Prudhoe Bay oil fields (Figure 1). Specific objectives were to: (1) determine the importance of this region to waterbirds, (2) derive a wetland classification system that identifies important

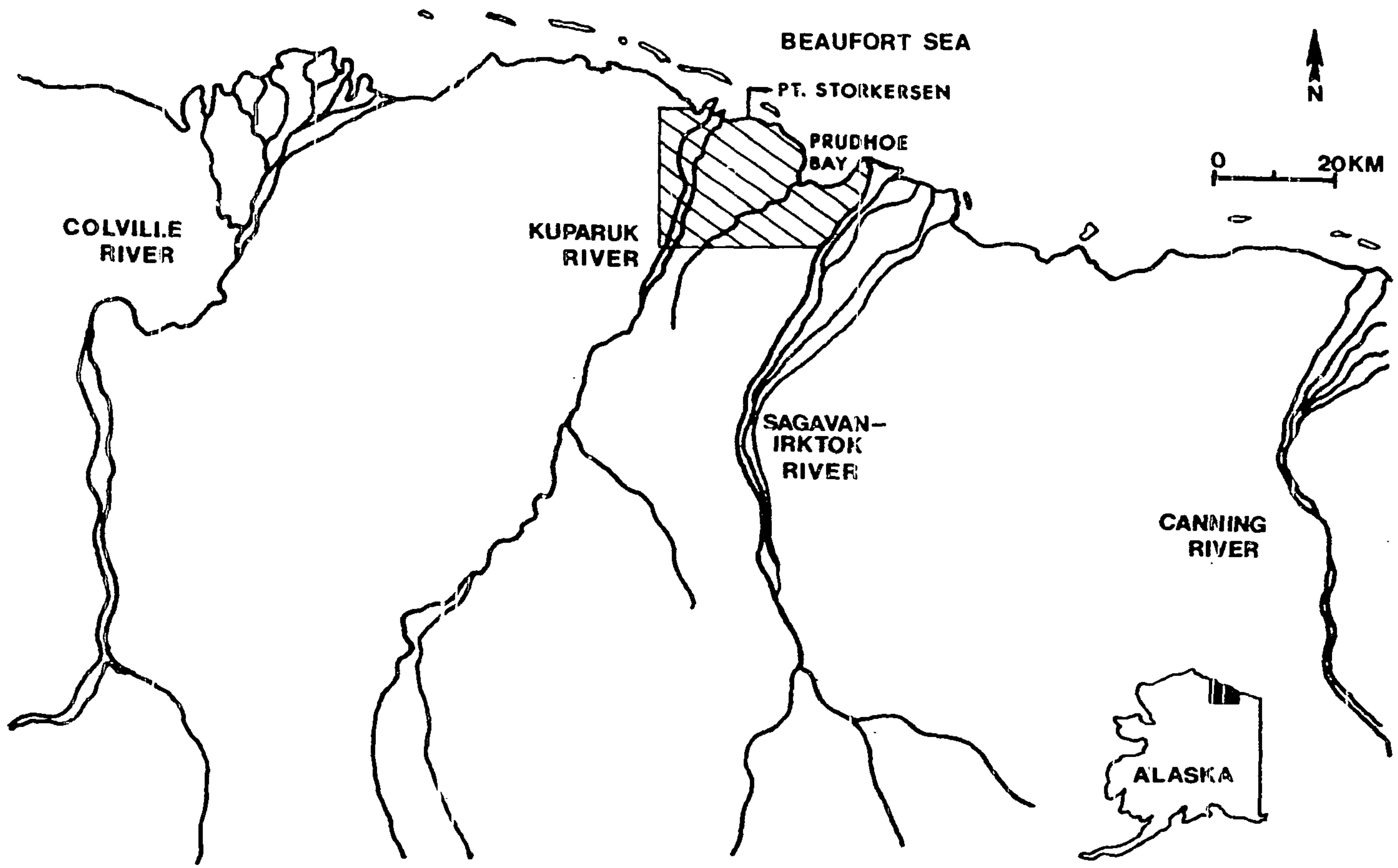

Figure 1. Location of Point Storkersen, the zone of intensive oil operations adjacent to Prudhoe Bay (shaded) and principal rivers on the Eastern Arctic Coastal Plain, northern Alaska

relationships between birds and wetlands, and (3) establish recommendations to reduce deleterious effects of petroleum development on the waterbird-wetlands community. This project was part of the Trans-Alaska Pipeline Investigation conducted by Special Studies personnel of the Bureau of Sport Fisheries and Wildlife, United States Fish and Wildlife Service.

STUDY AREA

The study site is located near Point Storkersen (Lat. 70°25'N, Long. 148°15'W) on the Arctic Coastal Plain adjacent to the Beaufort Sea (Figure 1). Efforts were confined mainly to an 18 km^2 area bordering the Beaufort Sea coast on the north and extending inland 7 km. Several capped oil wells were present in the immediate vicinity of Point Storkersen, and current major oil operations were located 20 km southeast near Prudhoe Bay. The Kuparuk and Sagavanirktok Rivers form large deltas approximately 8 km northwest and 25 km southeast, respectively, of Point Storkersen (Figure 1). Elevations in the study area range from sea level at coastal lagoons to 10 m on surface residuals a few kilometers inland.

The Arctic Coastal Plain possesses an Arctic Climate (Watson, 1959) and is characterized by tundra vegetation (Spetzman, 1959; Wiggins and Thomas, 1962) and continuous permafrost (Wahrhaftig, 1965).

The coastal plain is an unglaciated emergent region of the continental shelf having very low relief and poor drainage. Total area exceeds 65,000 km^2, and the length is about 800 km. Typical relief features are numerous lake basins, polygonal ground, ice-cored mounds (pingos), and relief characteristics of streams and gentle slopes (Hussey and Michelson, 1966). Surficial materials on the study area and most of the coastal plain are marine silts, sands, and gravels of the Pleistocene Gubik Formation (Payne et al., 1951). East of the Colville River there are hills formed from Tertiary materials of the Sagavanirktok Formation.

Formation of thaw basins on the Arctic Coastal Plain may occur wherever water accumulates on the surface due to restricted drainage (Carson and Hussey, 1962). Basins most commonly originate in low-center polygonal areas and at junctions of ice wedges. Water impounded in these depressions is heated by insolation in summer and thaws the ground ice. Alternating processes of freezing, thawing, and water movement enlarge and deepen basins. As growth continues, shores are breached by thaw processes and drainage results. Consequently, much of the coastal plain land surface is marked by numerous drained basins which often contain a new generation of wetlands (Livingstone et al., 1958); new basins apparently form most readily where ice-rich zones thaw in the bottom of the drained lake.

Based on size and shape differences of thaw lakes, Carson and Hussey (1962) divide the coastal plain into Eastern and Western Sections, separated by a boundary paralleling the Colville River at approximately longitude 152 degrees west. Lakes in the Eastern Section, which include the study area, generally are smaller, ranging in length from approximately 10 ft (3 m) to rarely more than 1 mi (1.6 km). In the Western Section, wetlands frequently exceed 1 mi (1.6 km), and several are over 8 mi (13 km) long.

Thaw lakes are commonly elongate with the long axis oriented 10 to 15 degrees west of true north. According to Carson and Hussey (1962), regularity in basin orientation is caused by a system of circulation currents set up in the lakes by prevailing northeasterly winds.

SECTION I: BIRD POPULATIONS

PROCEDURES

Abundance of loons (Gaviidae), waterfowl (Anatidae), plovers (Charadriidae), and jaegers (Stercorariidae) was appraised by weekly censuses conducted by two or three men. Birds were counted on two 2.6-km^2 (1-mi^2) plots in 1971 and on the same two areas and an additional plot of the same size in 1972 and 1973. The three areas are sections 13, 24, and 25 of R 13 E, T 12 N on the 1970 U. S. Geological Survey maps 2561 1 NW and 2561 1 SW. Because home ranges of whistling swans (Olor columbianus) were larger than the census plots, swan densities were estimated from observations on an 18-km^2 area frequently traversed by the investigators.

Other birds were counted on an 8-km, 100-m wide belt transect in 1971 and on nine widely spaced quadrants totaling 1.6 km^2 in 1972 and 1973.

Nests found in the study area were marked with a garden wand and the location recorded on a map. No attempt was made to find all nests. Nests were rechecked about once a week to determine clutch size and nest success. Any nest in which one or more eggs hatched was considered successful.

Field seasons extended from either 30 or 31 May to 14 August during 1971 to 1973. The author visited the study area on 1 and 2 September, 1973.

NESTING SPECIES

Eighteen of the 24 species arrived when snow covered more than 75 percent of the tundra (Table 1). Water used by black brant, ducks, and red phalaropes (Phalaropus fulicarinus) at this time occurred in tundra depressions or partially thawed ponds. Other species usually occupied snowfree patches of tundra. The arctic loon (Gavia arctica) and red-throated loon (G. stellata) were among the last birds to arrive, presumably because they require water in large ponds, which thaw late.

Before conditions were suitable on the nesting grounds at Point Storkersen, birds gathered in nearby staging areas. On 30 May 1972, snow covered the study area, but an extensive zone partially free of snow and ice surrounded oil facilities a few kilometers south of Prudhoe Bay. Most species that nested at Point Storkersen were abundant in the open areas. Each year, arctic loons (Gavia arctica), red-throated loons (G. stellata), and king eiders (Somateria spectabilis) concentrated in deltas of the Sagavanirktok and Kuparuk Rivers and adjacent zones of the Beaufort Sea. Water occurred early in these areas because rivers carried melt water to the coast from the phenologically advanced Arctic Foothills and southern coastal plain.

Peak densities of birds during June appear in Table 2; lowest and highest values during the three years are shown. Of the total number of birds in the study area each spring, shorebirds (plovers, sandpipers, and phalaropes) comprised 60 to 70 percent, and waterfowl represented about 15 percent. Red phalaropes occurred in the highest densities, ranging from 19

Table 1. First sightings of birds in relation to spring thaw, 1971-1973

Species	Range of arrival dates	Percent snow cover
Whistling Swan (*Olor columbianus*)	-[a]	>90
White-fronted Goose (*Anser albifrons*)	-[a]	>90
Ruddy Turnstone (*Arenaria interpres*)	-[a]	>90
Dunlin (*Calidrus alpina*)	-[a]	>90
Baird's Sandpiper (*Calidrus bairdii*)	-[a]	>90
Semipalmated Sandpiper (*Calidrus pusillus*)	-[a]	>90
Glaucous Gull (*Larus hyperboreus*)	-[a]	>90
Lapland Longspur (*Calcarius lapponicus*)	-[a]	>90
Snow Bunting (*Plectrophenax nivalis*)	-[a]	>90
American Golden Plover (*Pluvialis dominica*)	[a]-1 June	>90
Oldsquaw (*Clangula hyemalis*)	[a]-3 June	>75
Pintail (*Anas acuta*)	[a]-7 June	>75
Parasitic Jaeger (*Stercorarius parasiticus*)	1-3 June	>75
Red Phalarope (*Phalaropus fulicarinus*)	1-3 June	>75
King Eider (*Somateria spectabilis*)	1-3 June	>75
Black-bellied Plover (*Pluvialis squatarola*)	1-4 June	>75
Black Brant (*Branta nigricans*)	2-3 June	>75
Long-tailed Jaeger (*Stercorarius longicaudus*)	2-4 June	>75
Pectoral Sandpiper (*Calidrus melanotos*)	2-5 June	50-75
Northern Phalarope (*Lobipes lobatus*)	2-7 June	50-75
Red-throated Loon (*Gavia stellata*)	5-10 June	25-50
Spectacled Eider (*Somateria fischeri*)	7-10 June	25-50
Arctic Loon (*Gavia arctica*)	7-12 June	25-50
Buff-breasted Sandpiper (*Tryngites subruficollis*)	7-14 June	0-50

[a]Birds on study area when investigators arrived on 30 or 31 May.

to 37 birds per km^2. Densities of pintails (*Anas acuta*), oldsquaws, and king eiders (*Somateria spectabilis*) were highest among waterfowl. Lapland longspurs (*Calcarius lapponicus*) varied from 10 to 25 birds per km^2, and they constituted the majority of upland birds.

Table 2. Peak densities of birds in June and August as shown by lowest and highest values recorded during 1971 to 1973

Species	No. per km^2 June Low	June High	August 1-15 Low	August 1-15 High
Arctic Loon	1.6	1.6	1.6	2.0
Red-throated Loon	1.2	1.6	0.8	1.6
Whistling Swan	0.1	0.1	0.4	0.4
Black Brant[a]	2.0	5.1	---	---
White-fronted Goose[a]	0.8	1.6	2.7	8.6
Pintail[b]	4.3	7.8	8.6	21.1
King Eider	3.5	4.3	0.4	1.2
Spectacled Eider	0.8	0.8	---	0.4
Oldsquaw	4.3	5.1	5.5	9.0
Golden Plover	0.8	1.6	0.4	5.9
Black-bellied Plover	0.4	0.4	0.4	2.3
Ruddy Turnstone	0.4	0.4	---	0.4
Buff-breasted Sandpiper	1	10	---	1
Pectoral Sandpiper	18	22	8	37
Dunlin	9	16	5	15
Baird's Sandpiper	3	4	1	5
Semipalmated Sandpiper	11	20	2	10
Red Phalarope	19	37	8	37
Northern Phalarope	1	2	---	3
Parasitic Jaeger	0.4	0.4	0.4	0.8
Long-tailed Jaeger	0 2	0.4	---	0.4
Glaucous Gull	0.1	0.2	0.3	0.3
Lapland Longspur	10	25	2	5
Snow Bunting	1	3	3	5

[a]Nonbreeders comprised 50 to 75 percent of the population in June.

[b]Nonbreeders comprised over 90 percent of the population in June.

Populations of most species in June were breeding birds. Pintails, however, were predominantly nonbreeders because males always comprised more than 80 percent of the population. Moreover, only two nests were found, and no broods were seen. Nonbreeders formed approximately 50 to 75 percent of the black brant and white-fronted goose (Anser albifrons) populations in June.

Nest initiation by summer residents closely followed their arrival to the study area (Table 3). Whistling swans, semipalmated sandpipers (Calidrus pusillus), and lapland longspurs began nesting first, and loons and buff-breasted sandpipers (Tryngites subruficollis) started nesting last. Laying was late in 1972 (Table 3), especially for early nesters, due to a delay of approximately one week in thawing of snow and ice in nesting habitats. Nesting by species occurred mainly during periods shown in Figure 2.

Clutch size statistics in Table 3 represent those nests in which egg numbers did not change on subsequent nest checks, usually one week apart.

Production of young on the study area was highest in 1972 (Table 4). Reduced predation by arctic foxes (Alopex lagopus) on eggs of loons, eiders, shorebirds and jaegers seemed to be a principal factor. Foxes were observed hunting on the study area almost daily in 1971 and 1973, but no fox activity was seen until late July in 1972. In contrast, the number of avian predators such as jaegers, glaucous gulls (Larus hyperboreus), and common ravens (Corvus corax) did not appear to change in the three years. Breeding pairs of white-fronted geese, dunlins, (Calidrus alpina), and red phalaropes were highest in 1972, also resulting in greater densities of young.

In addition to recruitment of young, emigration and immigration of birds influenced composition and densities (Table 2) of populations in

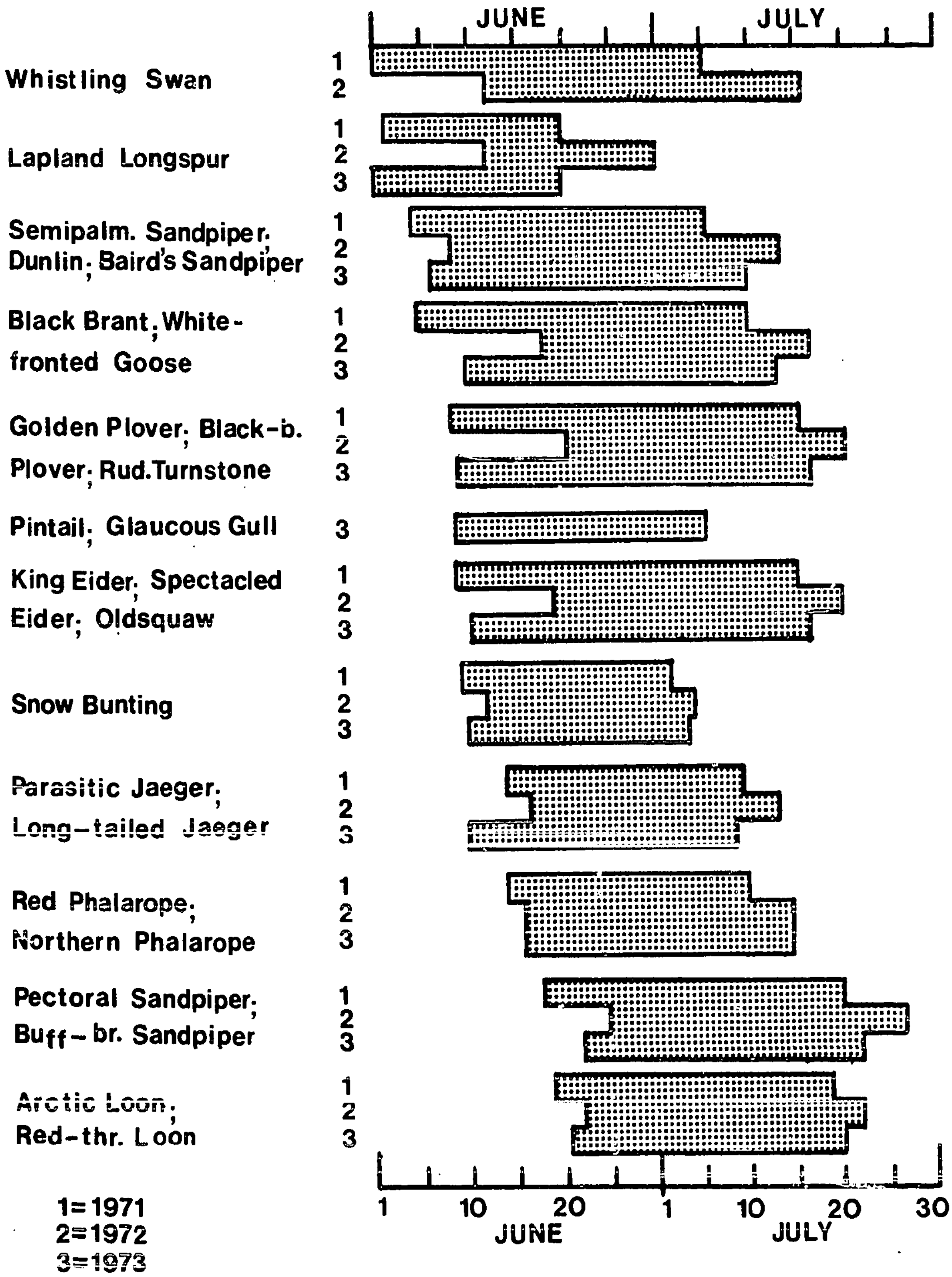

Figure 2. Duration of the nesting season for birds at Point Storkersen, 1971-1973

Table 3. Estimated date laying began and clutch size of birds

Species	No. of nests	Est. date first egg laid in June			Clutch size			
		1971	1972	1973	Mean	Mode	Range	No.
Arctic Loon	42	20	23	21	2.0	2	-2-	23
Red-thr. Loon	28	18	25	21	1.8	2	1-2	21
Whistling Swan	4	1	12	--	3.0	3	-3-	3
Black Brant	11	5	18	12	5.0	5	-5-	4
White-fr. Goose	8	5	15	9	4.7	4	3-8	7
Pintail	2	--	--	8	6	6	6	1
King Eider	32	8	19	10	4.5	4	2-7	17
Spect. Eider	3	--	21	--	4.5	4-5	4-5	2
Oldsquaw	16	9	19	23	6.7	7	6-7	3
Golden Plover	13	7	22	9	3.8	4	3-4	10
Black-b. Plover	1	--	20	--	4	4	4	1
R. Turnstone	1	--	20	--	4	4	4	1
Buff-br. Sandp.	4	17	24	22	3.8	4	3-4	4
Pectoral Sandp.	2	23	26	--	4.0	4	-4-	2
Dunlin	9	20	7	10	4.0	4	-4-	7
Baird's Sandp.	5	--	10	--	3.6	4	3-4	5
Semipalm. Sandp.	34	4	8	6	3.9	4	3-4	29
Red Phalarope	46	14	15	15	3.8	4	3-4	30
No. Phalarope	2	14	20	--	4.0	4	-4-	2
Par. Jaeger	7	14	16	10	2.0	2	-2-	7
Long-t. Jaeger	4	18	18	12	2.0	2	-2-	4
Glaucous Gull	3	--	--	10	3.0	3	-3-	2
Lapland Longspur	15	2	7	1	5.6	6	3-7	9
Snow Bunting	8	9	12	10	6.0	6	-6-	2

August. Changes were most noticeable for sexually dichromatic species. King eiders and spectacled eiders (Somateria fischeri) migrated to sea; males abandoned their mates in the last week of June or the first week of July, and females unsuccessful at nesting left by August. Male oldsquaws moved to the coastal Beaufort Sea in the second or third week of July to

Table 4. Estimates of nest success and production for birds in the Point Storkersen area

Species	1971 Percent nest success (No.)	1971 Average young per km^2	1972 Percent nest success (No.)	1972 Average young per km^2	1973 Percent nest success (No.)	1973 Average young per km^2
Arctic Loon	28(14)	0.4	92(12)	0.7	53(15)	0.6
Red-thr. Loon	33(6)	0.3	78(9)	0.6	45(9)	0.4
Whistling Swan	100(1)	0.2	100(1)	0.2	100(1)	0.2
Black Brant	0(4)	--	0(2)	--	0(2)	--
White-fr. Goose	100(1)	0.6	100(4)	1.4	50(2)	0.5
Pintail	--	--	--	--	0(2)	--
King Eider	0(3)	0.4	15(13)	1.6	0(16)	0.4
Spect. Eider	--	--	50(2)	0.2	0(1)	--
Oldsquaw	0(4)	--	0(6)	0.3	0(6)	--
Golden Plover	25(4)	0.4	60(5)	1.0	33(3)	0.6
Black-b. Plover	--	0.2	100(1)	0.2	--	0.2
R. Turnstone	--	--	0(1)	0.2	--	--
Buff-br. Sandp.	0(1)	--	50(2)	0.4	0(1)	--
Pectoral Sandp.	0(1)	0.4	--	2.7	--	3.9
Dunlin	0(2)	1.6	100(4)	13.3	33(3)	9.8
Baird's Sandp.	--	0.4	67(3)	2.0	0(1)	1.2
Semipalm. Sandp.	18(13)	2.3	88(8)	3.9	75(4)	6.6
Red Phalarope	17(23)	2.3	80(10)	11.7	25(8)	6.6
No. Phalarope	0(1)	0.4	--	0.4	--	0.4
Par. Jaeger	0(2)	--	100(2)	0.6	50(2)	0.2
Long-t. Jaeger	0(1)	--	100(1)	0.2	0(1)	--
Glaucous Gull	100(1)	0.2	100(1)	0.2	--	--
Lapland Longspur	0(4)	1.2	80(5)	3.1	67(6)	5.9
Snow Bunting	67(3)	0.8	100(3)	0.8	100(2)	0.8
Total		11.9		45.5		38.3

pass their flightless stage. However, oldsquaw numbers increased on the study area in August because females without young grouped on a large lake for their wing-molt. Female red phalaropes gathered in large flocks and emigrated in late June or early July, and most adult males were gone by

August. Increased densities of white-fronted geese and pintails in August (Table 2) resulted from an influx of post-molting birds.

VISITORS

Birds observed at Point Storkersen but not found nesting in the study area are listed in Table 5. Species that visited from nearby nesting or roosting areas were the Canada goose (Branta canadensis), lesser snow goose (Chen caerulescens), common eider (Somateria mollissima), glaucous gull, arctic tern (Sterna paradisaea), and common raven. Based on brood sightings, a few Canada geese nested on the mainland approximately 10 to 15 km south of Point Storkersen and in the Kuparuk River Delta. In 1973, 40 lesser snow goose nests were found on Howe Island in the Sagavanirktok River Delta; approximately 50 percent of the nests were successful. The colony was established in 1971 (Gavin, 1972), and it represents the only known lesser snow goose colony in Alaska. Common eiders, glaucous gulls, and arctic terns nested on gravel islands a few kilometers off the sea coast. Although snowy owls (Nyctea scandiaca) were observed in all months of the study, their occurrence was irregular during weekly censuses.

Table 5. Birds observed at Point Storkersen that did not nest in the study area

Species	Date of first observation 1971	1972	1973	Status[a]	Total number seen	(Per-cent males)
Common Loon (*Gavia immer*)[b]	---	2 July	---	B	1	
Yellow-billed Loon (*G. adamsii*)	---	4 June	---	A	1	
Canada Goose (*Branta canadensis*)	19 June	4 June	4 June	D	110	
Lesser Snow Goose (*Chen caerulescens*)	4 June	4 June	8 June	D	105	
Mallard (*Anas platyrhynchos*)	4 June	2 Aug.	20 June	A,C	5	(100)
American Wigeon (*A. americana*)	2 June	9 June	2 June	A	145	(>80)
Shoveler (*A. clypeata*)	---	---	9 June	A	10	(60)
Green-winged Teal (*A. crecca*)	4 June	8 Aug.	6 June	A,B,C	65	(80)
Greater Scaup (*Aythya marila*)	4 June	---	14 June	A	7	(100)
Common Eider (*Somateria mollissima*)	7 June	---	9 June	D	3	(33)
Steller's Eider (*Polysticta stelleri*)	8 June	12 June	7 June	A	36	(50)
Surf Scoter (*Melanitta perspicillata*)	7 June	1 July	25 June	A,B	66	(100)
Red-breasted Merganser (*Mergus serrator*)	---	28 June	---	A	2	(100)
Rough-legged Hawk (*Buteo lagopus*)	5 Aug.	29 June	8 June	A,B,C	5	
Golden Eagle (*Aquila chrysaetus*)	---	9 July	---	B	1	
Peregrine Falcon (*Falco peregrinus*)	27 June	27 July	11 July	A,B,C	5	
Rock Ptarmigan (*Lagopus mutus*)	-[c]	-[c]	-[c]	A,C	17	(55)
Semipalmated Plover (*Charadrius semipalmatus*)	---	---	8 June	A	1	
Bar-tailed Godwit (*Limosa lapponica*)	---	4 June	---	A	2	
Lesser Yellowlegs (*Totanus flavipes*)	---	---	6 June	A	1	
Stilt Sandpiper (*Micropalma himantopus*)	30 July	1 Aug.	24 July	B,C	180	
Long-billed Dowitcher (*Limnodromus scolopaceus*)	21 June	25 June	25 June	A,B,C	75	
White-rumped Sandpiper (*Calidrus fuscicollis*)	2 June	---	---	A	20	
Common Snipe (*Capella gallinago*)	4 June	---	---	A	1	

Pomarine Jaeger (*Stercorarius pomarinus*)	-[c]	2 June	1 June	A,B,C	180
Thayer's Gull (*Larus thayeri*)	---	15 June	9 Aug.	A,C	2
Sabine's Gull (*Xema sabini*)	6 June	6 June	4 June	A	50
Arctic Tern (*Sterna paradisaea*)	4 June	9 June	5 June	E	250
Murre (*Uria* sp.)[b]	20 July	---	---	B	30
Tufted Puffin (*Lunda cirrhata*)[b]	---	12 Aug.	---	C	1
Snowy Owl (*Nyctea scandiaca*)	-[c]	-[c]	-[c]	A,B,C	40
Short-eared Owl (*Asio flammeus*)	-[c]	3 June	4 June	A	21
Horned Lark (*Eremophila alpestris*)	---	---	6 June	A	2
Cliff Swallow (*Petrochelidon pyrrhonota*)	7 June	---	---	A	1
Bank Swallow (*Riparia riparia*)	---	9 June	---	A	1
Common Raven (*Corvus corax*)	-[c]	16 June	5 June	E	150
Robin (*Turdus migratorius*)	---	---	-[c]	A	1
Wheatear (*Oenanthe oenanthe*)	---	8 June	---	A	1
Yellow Wagtail (*Motacilla flava*)	---	5 July	---	B	1
Wilson's Warbler (*Wilsonia pusilla*)	---	---	1 Sept.	C	1
Hoary Redpoll (*Acanthis hornemanni*)	---	2 June	6 June	A	100
Savannah Sparrow (*Passerculus sandwichensis*)	2 June	---	11 June	A	4
Tree Sparrow (*Spizella arborea*)	---	4 June	5 June	A	2
White-crowned Sparrow (*Zonotrichia leucophrys*)	---	2 June	---	A	2
Fox Sparrow (*Passerella iliaca*)	---	9 June	---	A	1

[a]Status: A = May or June visitor.
B = July visitor.
C = August or September visitor.
D = Species nests nearby.
E = Regularly foraging from nearby nesting or roosting sites.

[b]Individuals observed over coastal water of the Beaufort Sea.

[c]Birds on study area when investigators arrived on 30 or 31 May.

DISCUSSION

Water-related birds dominated the bird fauna near Point Storkersen. Of the 24 species that nested in the study area, 11 were swimming birds (loons, waterfowl, and phalaropes), and four were wading birds (Calidrus sandpipers). In addition, black-bellied plovers (Pluvialis squatarola), jaegers, and glaucous gulls occasionally used water areas. Lapland longspurs and snow buntings (Plectrophenax nivalis) were the only breeding passerines, primarily because brush and shrub habitats used by other species on the Arctic Slope (Kessel and Cade, 1958) do not exist on this portion of the coastal plain.

The number and composition of breeding birds near Point Storkersen corresponded with information published by Kessel and Cade (1958) for the coastal plain in general and by Andersson (1973) at Nuvagapuk Point, located 270 km east of Point Storkersen. Kessel and Cade (1958) reported 51 species of breeding birds, but less than 36 species were regular in occurrence. Andersson (1973) reported 30 species possibly nesting, and composition and densities of birds were similar to those reported in this paper.

The apparent geological and vegetational homogeneity of the coastal plain in the Prudhoe Bay oil fields indicates that the avifauna at Point Storkersen is representative of the region.

SECTION II: WETLANDS AND THEIR USE BY WATERBIRDS

PROCEDURES

Physical and vegetational characteristics of aquatic habitats were appraised during late June and early August of 1972 and 1973. Sampling procedures in 1972 involved determining water depths, hydrogen ion concentration (pH), and the composition and distribution of aquatic plants. Water depths, recorded as the distance from water surface to the surface of basin sediments, were measured 1 m from the eastern and western shores and in the center of the basin. The two shoreward measurements and two measurements in the central basin were used to calculate mean water depth of each wetland. Hydrogen ion concentration was determined using a Hach pH Kit (Model 17-N). In June, 1972, two line transects were established across each wetland in east-west and north-south directions, and the presence or absence of plants was recorded at 10 cm intervals along each transect. During August of 1972, visual estimates were made of the percent of each wetland containing vegetation. A comparison of values obtained from the quantitative technique used in June with August estimates provided a basis for adjusting visual estimates. In June and August, 1973, specific conductance of surface water was measured with a Hach Conductivity Meter (Model 2510) that recorded in micromhos per cm.

Wetlands sampled were those encountered while walking seven east-west line transects spaced approximately 1 km apart; four transects were 3.2 km in length, and three were 1.6 km long. In August, 1972, measurements of depth and vegetation were made in all wetlands within the areas (7.8 km^2) used to census loons and waterfowl.

Use of wetlands by loons and waterfowl was appraised by weekly ground surveys on two 2.6-km^2 (1-mi^2) plots in 1971 and on the same two areas and an additional area of the same size in 1972 and 1973. Base maps prepared from U. S. Geological Survey Orthographic Maps were used to record locations of waterbirds.

To evaluate why pintails and king eiders preferred certain wetlands, their diurnal activities were assessed twice during continuous daylight in June, 1973. Each wetland was scanned with a 30-power spotting scope at 30- or 60-minute intervals, and birds were observed long enough to ascertain their activity. Other species did not concentrate in numbers sufficient to provide a similar appraisal of activities.

Food habits of loons were determined by examining contents of the upper digestive tracts of arctic and red-throated loons. Foods used by geese were identified by observing individuals feeding and examining feeding sites for grazed vegetation. Foods consumed by swans and ducks were not assessed.

MEASUREMENTS OF WETLAND CHARACTERISTICS

Characteristics measured at wetlands and used in developing the classification system were: (1) size and depth; (2) aquatic plants; (3) water chemistry; and (4) thermal regimes.

Size and Depth

Relationships between surface area and water depth of wetlands are shown in Figure 3; surface area classes are of unequal sizes due to fewer large wetlands. Mean depth of the smaller classes of first generation basins increases directly with increasing surface area. The relationship is less predictable in the large size classes because of partial drainage of these wetlands by intersecting ice wedge troughs or union with adjacent lower basins. In contrast, wetlands formed in drained basins (second generation wetlands) show a uniform increase in mean depth as basin area increases in size. Presumably, drainage of these basins is less frequent than first generation wetlands due to their relatively low position in the bottom of drained basins.

First generation wetlands can attain considerable size before drainage occurs. Several lakes over 150 ha and more than 1.5 m deep occur within 10 km of the study site. Consequently, the depth-area curve for that region would differ markedly from Figure 3. Inevitably, however, the basin erodes and drains, and a new generation of wetlands develops in the old basin by the thaw process.

Factors other than drainage also contribute to variations in the direct relationship between basin area and water depth. Carson and Hussey (1962) ascribed differences in depth of similar size thaw lakes near

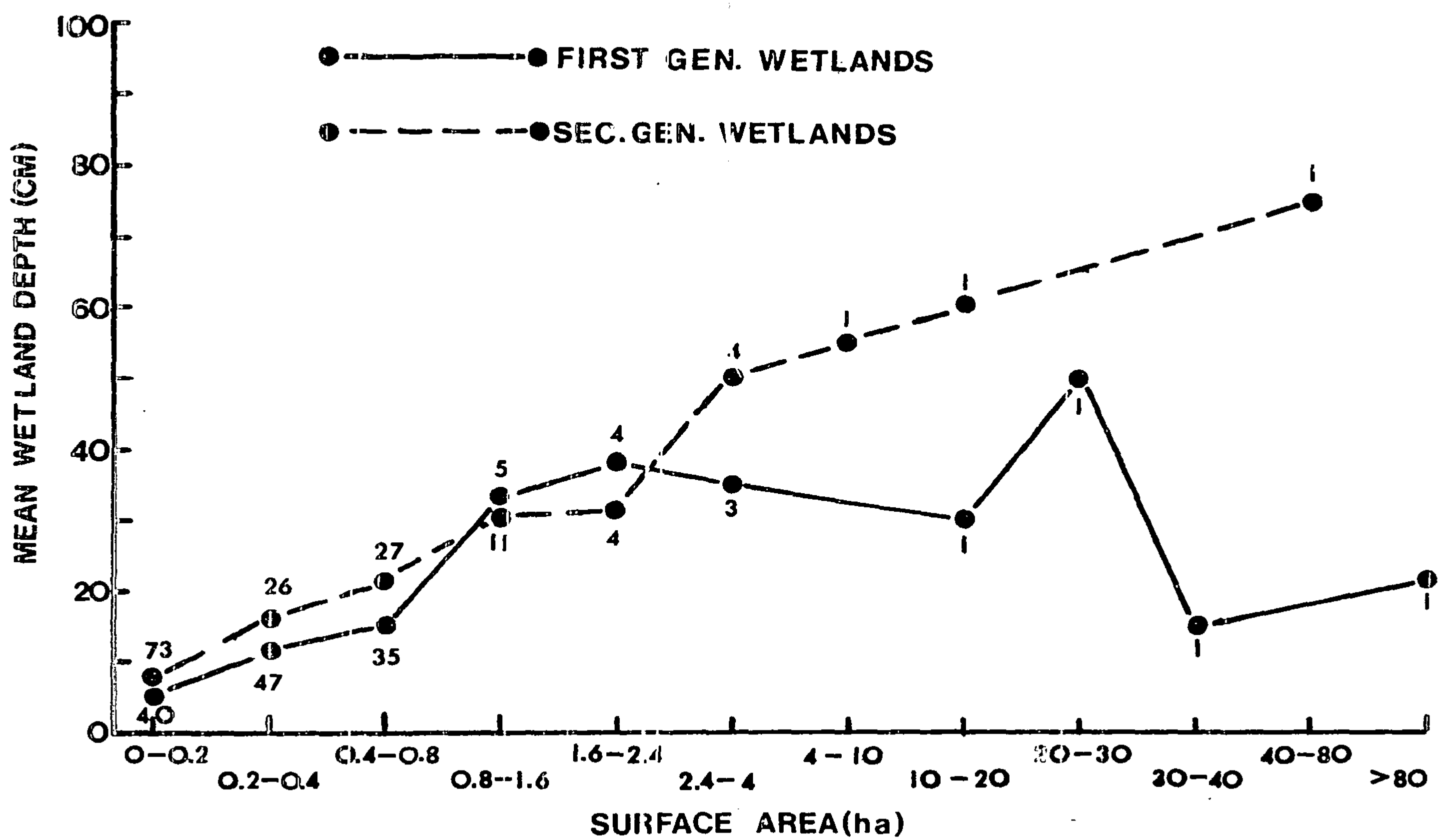

Figure 3. Relationship between mean water depth and surface area of first and second generation wetlands, 2 to 8 August, 1973. The number of wetlands measured is shown next to each dot

Barrow, Alaska (Lat. 71°20'N, Long. 156°50'W) to irregularities in ground ice distribution, particle size of sediments, and individual basin histories. In the Point Storkersen area, a noticeable cause was recent coalescence of two or more basins which, in effect, increases area relative to water depth.

Aquatic Plants

Distribution of vascular plants in wetlands on the coastal plain is influenced by water depth (Britton, 1957:104). Figure 4 illustrates the occurrence of *Carex aquatilis* (water sedge) and *Arctophila fulva* (pendant grass) in relation to water depth of wetlands near Point Storkersen; depth measurements were taken at the shallow and deep water margins of stands. Of 69 stands examined, *C. aquatilis* was prevalent on moist soils and progressively less common at increasing water depths. Plants were not found at depths greater than 30 cm. Optimal depths for *A. fulva* (52 stands) occurred between 20 cm and 45 cm, and plants were absent in depths exceeding 80 cm. Few stands were encountered that contained large numbers of both species, and an obvious belted pattern in wetlands resulted where *C. aquatilis* formed shoreward stands abutting deeper water stands of *A. fulva*. The intersection of depth-frequency lines in Figure 4 indicates that 15 cm is the depth at which an interface between the two species most frequently occurs. Because *C. aquatilis* and *A. fulva* are dominant vascular plants in freshwater habitats near Point Storkersen and throughout the coastal plain (Spetzman, 1959), the distribution of these emergents is a good indicator of wetland development.

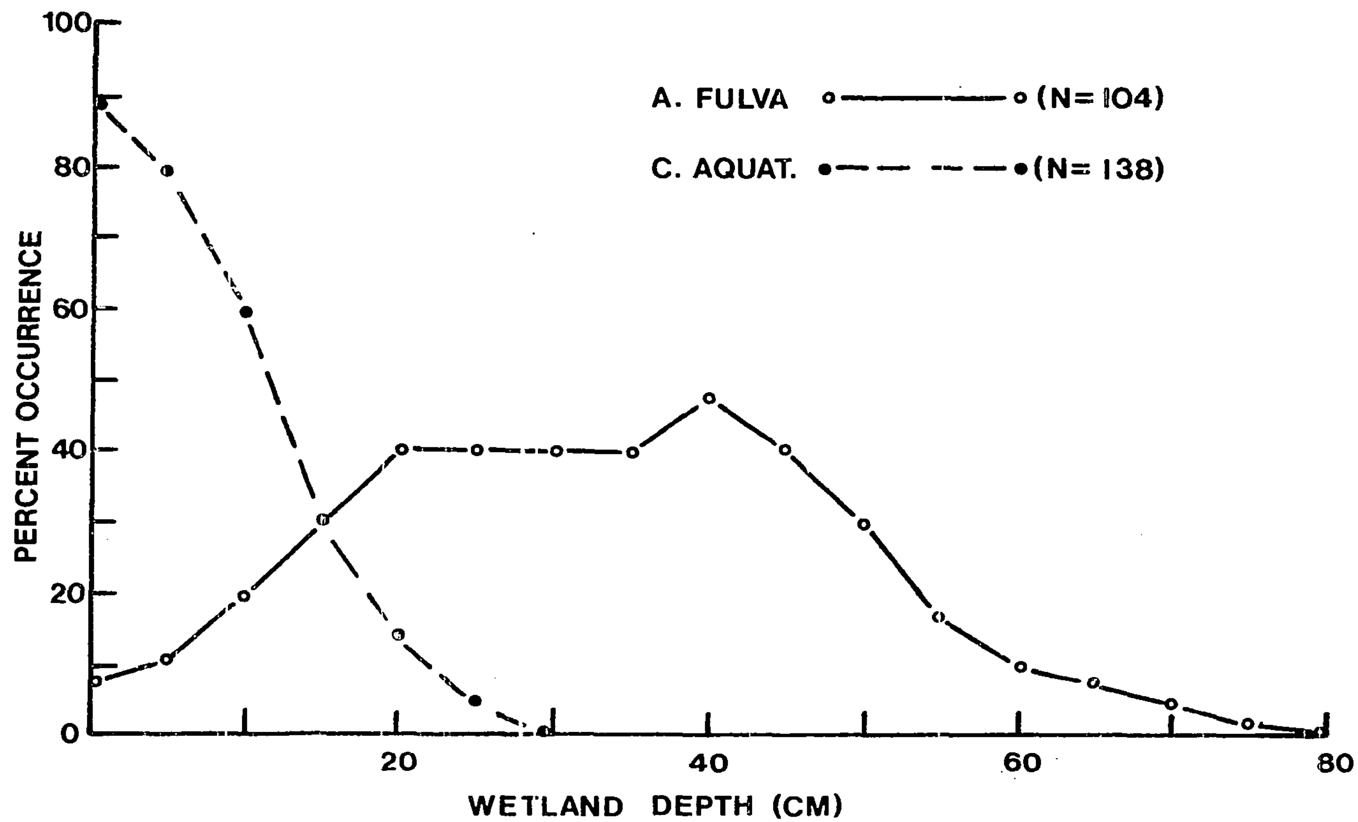

Figure 4. Percent occurrence of Carex aquatilis and Arctophila fulva in relation to water depth. Depth measurements (N) were taken at the shallow and deep water margins of stands found in 80 wetlands during 2 to 3 August, 1973.

Other vascular plants found in freshwater wetlands near Point Storkersen were less widely distributed than Carex aquatilis and Arctophila fulva. Eriophorum angustifolium, E. russeolum, and E. scheuchzeri often formed mixed stands with C. aquatilis, but the Eriophorum spp. were less aquatic than C. aquatilis; few plants grew in depths over 10 cm. E. angustifolium frequently formed nearly pure stands on moist soils and on low-center polygon basins covered by a few centimeters of water. Hippuris vulgaris, Caltha palustris, Cardamine pratensis, Ranunculus pallasii, R. gmelini, and R. hyperboreus were usually found submerged and growing from a thick peat substrate. Vegetation associated with tidal ponds and lagoons will be discussed in relation to salinity.

Water Chemistry

Tests for major ions in wetlands were not conducted in this study, but Livingstone et al. (1958) list the concentrations of ions measured in a lake near the coast at Barrow and two lakes on the southern coastal plain (Lat. 69°50'N, Long. 155°27'W). Extrapolation of their results to the Eastern Coastal Plain suggests that sodium and chloride ions predominate in wetlands near the coast, such as those near Point Storkersen, and calcium and bicarbonate ions are the major constituents of lakes and ponds further inland.

Wetlands exhibit a specific conductance gradient related to proximity to the sea (Table 6). Measurements are placed in salinity ranges published by Stewart and Kantrud (1972) for prairie potholes. Those basins connected to the sea or periodically flooded by sea water during tides or storms (coastal lowlands in Table 6) contained brackish or subsaline water (3800

Table 6. Specific conductance and hydrogen ion concentration (pH) of wetlands near Point Storkersen in early August

Location of wetlands	Specific conductance (micromhos/cm)			pH		
	Mean	Range	No.	Mean	Range	No.
Coastal lowlands	>14,440[a]	3,800 - >20,000[a]	11	8.9	-8.9-	3
Coastal uplands	730	405 - 1,370	17	8.7	8.5-8.9	11
Inland (>1 mile)	365	220-550	50	8.5	6.8-9.0	43

[a]Maximum reading on meter was 20,000 micromhos/cm.

to >20,000 micromhos/cm) when ten such wetlands were examined from 2 to 9 August, 1973. Specific conductivity of coastal sea water at this time varied from 16,000 to above 20,000 micromhos/cm (N=3), values which are within the normal subsaline range (14,000 to 45,000 micromhos/cm). Wetlands lying within a few meters of the coast but situated above sea level (coastal uplands) were slightly brackish, and measurements were never higher than 1,370 micromhos/cm in August. As distance from the sea increased, conductivity of waters decreased, and a boundary of 500 micromhos/cm between slightly brackish and freshwater wetlands occurred approximately 1.5 km inland from the coast.

Seasonal increases in specific conductance of wetlands were apparent from measurements taken in late June and early August. Presumably, this results from dilution by relatively pure melt water during spring breakup, followed by declining water levels during summer. By August, ionic constituents are more concentrated and conductivity readings were on the order of 50 to 100 percent higher than June measurements.

The influence of salinity on the distribution and composition of aquatic plants was apparent in coastal wetlands containing brackist or subsaline water. These basins lacked *Carex aquatilis* and *Arctophila fulva*. Moreover, the only plants found in these wetlands were *Carex subspathacea* and *Puccinellia phryganodes*, two relatively prostrate and diminutive species that inhabit shallow water and adjacent uplands. According to Wiggins and Thomas (1962), both species tolerate tidal flats periodically covered with sea water. During this investigation, neither was found outside zones flooded by sea water.

Surface water tested in aquatic habitats ranged in pH from slightly acid (6.8) to very basic (9.0) (Table 6). Waters of coastal lowlands had pH values of 8.9 (N=3), measurements identical to coastal Beaufort Sea water.

Thermal Regimes

The magnitude of diurnal temperature fluctuations in wetlands, monitored by continually recording thermographs, is inversely related to basin volume (Figure 5). Temperatures in shallow, flooded depressions underwent daily variations even greater than those recorded for ambient air temperature at an elevation of 2 m above ground. Conversely, the largest and deepest wetland exhibited the smallest diurnal temperature changes.

Most arctic lakes and probably all coastal plain wetlands are essentially isothermal in summer. Livingstone et al. (1958) found no thermal stratification even in Arctic Mountain lakes 18 m deep. Near Barrow, con-

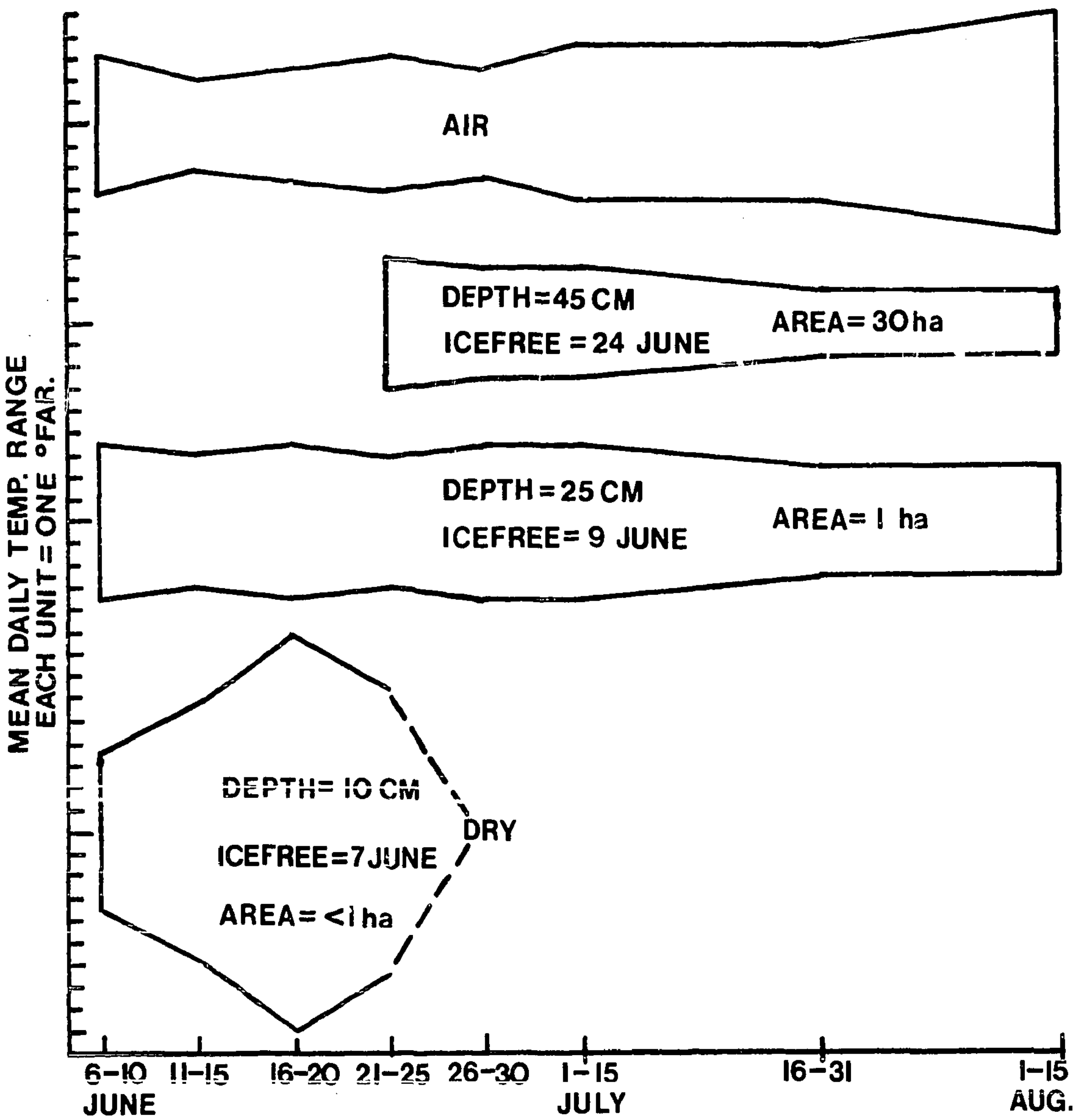

Figure 5. Mean daily range of temperatures measured in three wetlands with different volumes of water and in a weather station located 2 m above ground

stant mixing of waters by wind maintains an isothermal condition in all wetlands (Brewer, 1958), although Carson and Hussey (1962) did find some stratification in shallow, marshy portions of lakes where water is free from intense wave agitation.

Because ice forms to depths of about 2 m in coastal plain lakes (Brewer, 1958), wetlands near Point Storkersen were completely frozen until late May or early June. Open water first occurred where snow melt filled tundra depressions and where snow and surface ice thawed on shallow ponds. Once thaw began, ice in these shallow wetlands melted from top to bottom within a few days. Large, deep lakes thawed last, and they were completely open by late June, 1971, and early July, 1972, and 1973. In contrast to smaller wetlands, ice in lakes was floating after it had melted sufficiently near the edges to become free from the bottom. This resulted in a moat of open water surrounding a large, central cake of ice which persisted for up to two weeks.

WETLAND CLASSIFICATION SYSTEM

A wetland classification system relevant to avian distribution and comparable to those developed in temperate North America by Martin et al. (1953), Shaw and Fredine (1956), and Stewart and Kantrud (1971) is not available for arctic wetlands. Aquatic habitats of birds have been described for the Colville River Valley (Kessel and Cade, 1958) and upper Kaolak River (Maher, 1959), but categories were necessarily broad and factors influencing seasonal use by birds were not identified. Bee and Hall (1956) and Wiggins and Thomas (1962) included several types of wetlands in their classification of biotic communities on the Arctic Slope, but their wetland classes were too general to relate to bird use.

The wetland classification system described in this paper (Table 6) is designed to: (1) delineate aquatic habitats preferred by loons and waterfowl and (2) provide classes of wetlands useful for wetland inventories. Although other species, especially phalaropes, use aquatic habitats, loons and waterfowl were studied because they are conspicuous and, therefore, more appropriate indicators of changes in waterbird populations.

Table 7 lists the eight wetland classes comprising the classification system and criteria used to distinguish between classes. Because of the large size range of wetlands, a sliding scale was used to delineate the shoreward and central zones. The shore zone extended approximately 10 m from shore in lakes, 6 m in large ponds, and 2 m in small wetlands. The shoreward zone in large lakes is an obvious sublittoral shelf that abruptly falls to the deeper central zone. These zones are not distinct in ponds, except that the shoreward zone usually is most shallow, and, consequently,

Table 7. Criteria used to delineate classes of wetlands near Point Storkersen

Wetland designation	Dominant emergents: Shore zone	Dominant emergents: Central zone	Conductivity	Common size
Flooded Tundra (Class I)	*Carex aquatilis* or *Eriophorum angustifolium*	*C. aquatilis* or *E. angustifolium*	Fresh or slightly brackish	Pond
Shallow-*Carex* (Class II)	*C. aquatilis*	Open	Fresh or slightly brackish	Pond
Shallow-*Arctophila* (Class III)	*C. aquatilis* or *Arctophila fulva*	*A. fulva*	Fresh or slightly brackish	Pond
Deep-*Arctophila* (Class IV)	*A. fulva*	Open	Fresh or slightly brackish	Pond or lake
Deep-open (Class V)	Open	Open	Fresh or slightly brackish	Lake
Seasonal-mosaic (Class VI)	Basin interspersed with *A. fulva*, *C. aquatilis*, and open water		Fresh or slightly brackish	Lake
Coastal Wetlands (Class VII)	*Puccinellia phryganodes*, *C. subspathacea*, or Open	Open	Brackish or subsaline	Pond or lagoon
Beaded Streams (Class VIII)	*A. fulva*, *C. aquatilis*, or Open	Open or *A. fulva*	Fresh or slightly brackish	Pond= Bead

vegetation often is found only near shore. Zones of wetlands are considered open if vegetation occurs in less than five percent of the area.

As used in this paper, the term wetlands refers to nonfluvial waters and those small fluvial waters identified as beaded streams by Hussey and Reckendorf (1963). Basin size is used in the system only to distinguish two size categories, ponds and lakes, following the definition by Stewart and Kantrud (1971) that ponds are less than 50 acres (20 ha) and lakes exceed 50 acres. The distinction is used in this paper to indicate that some classes possess wetlands of only pond or lake size.

The eight classes of wetlands are described as follows:

Flooded Tundra (Class I)

Shallow waters form during spring thaw when melt water is trapped in tundra depressions. The ponds formed in low centers of polygonal ground often produce a mosaic pattern. Water depths in June rarely exceed 10 cm, and surface water is absent or only a few centimeters deep by August. Unlike other classes, basins of these wetlands are poorly defined because *Carex aquatilis*, *Eriophorum angustifolium*, and other plants tolerant of periodic flooding cover basin sediments.

Shallow-*Carex* (Class II)

Shallow ponds having a gently sloping basin containing *Carex aquatilis* in shoreward areas and a central open water zone. At Point Storkersen, maximum water depths in June vary between 10 cm and 30 cm. By August, water levels decline due to evaporation or drainage and sediments may be exposed over a large portion of the basin.

Shallow-_Arctophila_ (Class III)

Ponds containing _Arctophila fulva_ in the central zone and shoreward stands of _A. fulva_ or _Carex aquatilis_. Shores are more abrupt than those of Class II ponds, and maximum water depths typically range from 20 cm to 50 cm. Bottom sediments usually are not exposed in August except along pond margins.

Deep-_Arctophila_ (Class IV)

Wetlands of either large pond or lake size that lack emergents in the central zone and contain stands of _Arctophila fulva_ near shores. These basins have abrupt shores and flat or gently sloping bottoms. Maximum water depths exceed 40 cm. Class IV wetlands are common as second generation basins resulting from melting of ice-rich zones in drained basins. Often they form extensive complexes with basins intersected by a network of low ridges.

Deep-Open (Class V)

Large, deep lakes that have abrupt shores, sublittoral shelves, and a deep central zone. Water depths are greater than in Deep-_Arctophila_ wetlands, and _A. fulva_ is absent or present in less than 5 percent of the basin. Maximum water depth of the largest and deepest lake was 1.1 m.

Seasonal-mosaic (Class VI)

Large, partially drained basins that contain a nearly continuous water surface in spring due to flooding of the bottom by melt water. By mid-July, water levels recede leaving a mosaic of vegetation and open water patterns. _Arctophila fulva_ grows along the margin of deeper pools and throughout shallow pools. Carex aquatilis forms stands wherever moist soils or a few cm of water occur. In late summer, relatively upland-like areas are present in some basins, and they are characterized by stands of Alopecurus alpinus and Dupontia fischeri growing on a moss substrate. Plant communities are most diverse and prolific in this class where the greatest variety of water conditions occur.

Coastal Wetland (Class VII)

Aquatic habitats that occupy low areas bordering the Beaufort Sea and within a zone directly influenced by sea water. Wetlands vary from lagoons always confluent with the sea to ponds periodically inundated by exceptionally high wind tides. Unlike all other classes, Coastal Wetlands are brackish or subsaline in specific-conductance, and they have a characteristic vegetation dominated by Carex subspathacea and Puccinellia phryganodes at basin margins and on adjacent flats. Two general modes of origin probably account for most Coastal Wetlands: (1) thaw basins breached by outward growth onto the sea beach or from inward erosion by sea ice or water and (2) lagoons and ponds resulting from the formation of sand or gravel spits by sea currents.

Beaded Stream (Class VIII)

Small streams consisting of a series of ice-wedge channels linked with pools that develop at ice-wedge intersections (Hussey and Reckendorf, 1963). Intersection pools often become greatly enlarged as contiguous ice-rich soils thaw and subside. Relationships between water depths and aquatic plants appear to be similar to those in ponds and lakes. Water depths usually are deep compared to nonfluvial wetlands of equivalent size, and vegetation distribution and composition corresponds to Shallow-*Arctophila* and Deep-*Arctophila* wetlands. During spring breakup, Beaded Streams flow with an appreciable current and flood surrounding lowlands creating extensive wetlands of the Flooded Tundra type. By mid-July, water is confined to stream channels and beads, and water movement is imperceptible. Beaded Streams are common throughout the coastal plain, and they are often the only class of wetlands in large areas of well-drained regions of the southern coastal plain.

ABUNDANCE AND DEVELOPMENT OF WETLANDS

A summary of the areal and numerical importance of wetland classes appears in Table 8, along with mean values of basin size, water depth, and occurrence of plants. The small, shallow Class I and II wetlands were by far most numerous and comprised one-half of the total area of all wetlands. Class V and VI lakes were few in numbers, but their large size contributed 26 percent of the total wetland area. The number of Coastal Wetlands (Class VII) averaged 2 per km^2 over the entire study area; however, all 29 basins were in one 50 ha area bordering the sea.

The following sequential description places wetlands of Classes I through VI into the perspective of basin development. Water impounded in tundra depressions or low center polygons (Flooded Tundra) initiates the thawing process that deepens the basin. As water depth increases, tundra plants, dominantly *Carex aquatilis* and *Eriophorum angustifolium*, are eliminated in the deeper central zone and restricted to shallow shoreward zones; wetlands of this stage are Shallow-*Carex* ponds. As subsidence continues, *Arctophila fulva* becomes established throughout the basin, forming Shallow-*Arctophila* ponds. Further thawing of the central zone causes depths not tolerated by *A. fulva*; consequently, distribution of *A. fulva* is confined to shore, and these basins are Deep-*Arctophila* wetlands. Deep-open lakes result when shoreward zones become too deep to support extensive stands of *A. fulva*. The final stage of first generation basins (Seasonal-mosaic lakes) occurs when shores erode and partial drainage lowers water levels to depths conducive for growth of aquatics. Further drainage creates expansive uplands where development of second generation wetlands

Table 8. Characteristics of classes of wetlands in the Point Storkersen study area, August, 1972

	% of total wetland area	Basins per km^2	Basins in sample	Wetland volume		% occurrence in wetland	
				Area (ha) $\bar{x}$ (S.D.)	August depth (cm) $\bar{x}$ (S.D.)	Sedges $\bar{x}$ (S.D.)	Arct. $\bar{x}$ (S.D.)
Flooded Tundra (I)	29	>100	47	0.1 (0.2)	3 (3)	84 (18)	1 (4)
Shallow-*Carex* (II)	21	35	263	0.3 (0.3)	12 (7)	7 (7)	0 (0)
Shallow-*Arctophila* (III)	4	6	19	0.6 (0.7)	22 (10)	7 (6)	52 (23)
Deep-*Arctophila* (IV)	11	5	39	1.8 (2.3)	35 (13)	2 (4)	14 (11)
Deep-open (V)	9	<1	2	46.0 (25.4)	60 (28)	0 (0)	1 (0)
Seasonal-mosaic (VI)	17	<1	3	46.4 (39.1)	22 (8)	32 (10)	18 (10)
Coastal Wetland (VII)	3	2	3	0.6 (0.6)	22 (11)	0 (0)	0 (0)
Beaded Stream (VIII)	5	2 beads	3 beads	3.8 (3.9)	47 (20)	4 (2)	32 (43)

follows the same thawing process. Deep pockets, caused by thawing of concentrated ground ice in partially drained lakes, probably do not drain even though other areas do. Such pockets are considered part of first generation Seasonal-mosaic lakes, and, as drainage continues, they become second generation wetlands.

Functional use of the classification system requires wetland indicators that are readily identifiable from either air or ground. Distribution of Arctophila fulva and Carex aquatilis provides the best determination of the stage of basin development in the classes of nonfluvial, freshwater thaw basins (Class I-VI). The two species are readily distinguished by late June because A. fulva becomes distinctly red in color while C. aquatilis is bright green. Coastal wetlands are easily identified because of their occurrence in low areas connected to the sea beach and typically bordered on the inland side by a line of driftwood and other debris windrowed by storm tides. In addition, Carex subspathacea and Puccinellia phryganodes form a characteristic mat-like sod that is distinct from more robust species growing near freshwater wetlands.

A wetland may have two or more regions which are morphologically and vegetationally distinct. This can occur where two wetlands originally of different classes have recently coalesced, or where embayments of Deep-open lakes are shallower than the lake-proper. Because differences were apparent in use of regions by birds, regions were classified separately.

Other wetlands not considered in this system are incised and braided streams, their deltas, and associated nonfluvial wetlands. Such waters contribute significantly to coastal plain wetlands and are valuable to birds (Kessel and Cade, 1958).

USE OF WETLANDS BY WATERBIRDS

Frequencies that wetlands were used by waterbirds (Table 9) were evaluated using a Chi-square 1 x 2 contingency table test. Preference for a wetland class by a species was assumed to occur if the number of birds that used wetlands in that class was significantly greater than the number of birds expected on those wetlands. The expected value was calculated by multiplying the total number of birds using wetlands in the class by the percent of the total wetland area covered by wetlands in the class. Observations of whistling swans using wetlands were limited; consequently, use of wetlands by swans was not tabulated or tested for significance.

Flooded Tundra (Class I)

Pintails fed and loafed on Flooded Tundra before and after their wing-molt in July (Table 9). Use was most intense during spring thaw when other wetlands were frozen.

Although not quantified, primary use of Flooded Tundra was by red phalaropes. Birds frequently were seen feeding or swimming in Class I basins throughout spring and summer.

Shallow-*Carex* Ponds (Class II)

Although most species were observed on Shallow-*Carex* ponds, only adult oldsquaws and king eider hens with broods used the ponds in significant frequencies (Table 9). Use by oldsquaws, primarily pairs, was significant before nesting ($P<0.01$) and during nesting ($P<0.05$). Feeding was a common activity of oldsquaws on Class II ponds. Twelve of the 19 (69 percent) observations of king eider broods were on Shallow-*Carex* ponds. Birds were seen feeding in water or loafing on or near shore. Although their frequencies of use were not significant, adult king eiders often were seen feeding in waters of Class II ponds.

Table 9. Frequencies (percent) that loons and waterfowl used classes of wetlands. Numbers of birds observed during phases of summer residence and the number of king eider broods are in parentheses

	Arctic Loon			Red-throated Loon		
	Pre-nest (31)	Nest (79)	Post-nest[a] (57)	Pre-nest (55)	Nest (115)	Post-nest[a] (65)
Flooded Tundra (I)	--	--	--	--	--	--
Shallow-*Carex* (II)	--	5	9	2	6	2
Shallow-*Arctophila* (III)	--	3	-	3	8	3
Deep-*Arctophila* (IV)	52**	59**	52**	22*	33**	24**
Deep-open (V)	--	5	16*	--	--	3
Seasonal-mosaic (VI)	36**	18	16	73**	51**	65**
Coastal Wetland (VII)	6	5	5	--	--	--
Beaded Stream (VIII)	6	5	2	--	2	3
Total	100	100	100	100	100	100

[a]Adults and young.

[b]Adults only.

*Chi-square value significant (P<0.05).

**Chi-square value highly significant (P<0.01).

Black Brant			White-fr. Goose	Pintail			King Eider			
Pre-nest (55)	Nest (22)	Post-nest[a] (12)	Post-nest (189)	Pre-molt (544)	Molt (270)	Post-molt[b] (871)	Pre-nest (23	Nest (188)	Post-nest[b] (87)	Brood (19)
--	--	--	--	8	--	9	--	--	--	--
--	9	--	--	7	--	14	14	22	26	64**
--	--	--	3	26**	6	12**	7*	8*	8	5
9	91**	--	--	14	2	13	30**	42**	52**	26*
--	--	--	94**	1	--	--	--	8	6	--
18	--	--	3	37**	92**	46**	39**	9	5	5
73**	--	100**	--	2	--	3	7**	8**	3	--
--	--	--	--	5	--	3	3	3	--	--
100	100	100	100	100	100	100	100	100	100	100

Table 9. (Continued)

	Spectacled Eider			Oldsquaw			
	Pre-nest (20)	Nest (9)	Post-nest[b] (7)	Pre-nest (223)	Nest (261)	Post-nest[b] (345)	Total (3763)
Flooded Tundra (I)	--	--	--	--	1	--	3
Shallow-*Carex* (II)	--	--	--	31**	28*	5	12
Shallow-*Arctophila* (III)	--	--	--	5	3	--	10**
Deep-*Arctophila* (IV)	90**	89**	100**	40**	36**	9	22**
Deep-open (V)	--	11	--	2	10	85**	14**
Seasonal-mosaic (VI)	--	--	--	10	9	--	32**
Coastal Wetland (VII)	--	--	--	4	3	--	4
Beaded Stream (VIII)	10	0	0	8*	10**	1	3
Total	100	100	100	100	100	100	100

Six of the eight white-fronted goose nests found were less than 4 m from the edge of Shallow-Carex ponds. Other species constructed nests close to ponds or on islets, but frequencies of use were low: two of 42 arctic loon nests; five of 28 red-throated loon nests; one of 11 black brant nests; and six of 32 king eider nests.

Shallow-Arctophila Ponds (Class III)

Use of Shallow-Arctophila ponds by pintails was significant ($P<0.01$) during the periods before and after their wing-molt in July (Table 9). Shallow water and extensive stands of *A. fulva* provided feeding habitat and cover for birds. Most other species were seen on Class III wetlands, but less frequently than pintails; use by king eiders was significant ($P<0.05$) before and during nesting.

One arctic loon nest and three red-throated loon nests were located on detritus platforms in ponds.

Deep-Arctophila Wetlands (Class IV)

Deep-Arctophila ponds and lakes were principal aquatic habitats for all waterbirds except white-fronted geese and pintails (Table 9).

Loons

Use of Class IV wetlands by arctic loons and red-throated loons was significant throughout summer (Table 9); however, red-throated loons showed an even greater preference for seasonal-mosaic lakes (Class VI). The proportion of observations of arctic loons on Class IV wetlands ranged from 52 percent before and after nesting to 59 percent during the nesting period. Sightings of red-throated loons were less frequent: prenesting (22 percent); nesting (33 percent); and postnesting (24 percent). Only adult arctic loons were observed feeding or capturing food for young in freshwater wetlands (Table 10). Red-throated loons captured food at sea, and, during brood-rearing, adults returned to brood-ponds with fish for young.

Because of relatively deep water in Class IV wetlands, nests of arctic and red-throated loons were placed on islands or shores rather than on detritus platforms such as those used in shallow wetlands.

Waterfowl

Whistling swans used Deep-Arctophila wetlands for escape cover. In 1971 and 1972, a pair nested adjacent to a large complex of Class IV ponds. When I approached the pair and three cygnets, they evaded by rapidly moving from pond to pond until the birds were on the other side of the complex.

King eiders and spectacled eiders selected Class IV wetlands in all phases of their reproductive cycle at Point Storkersen (Table 9). Frequencies of use by king eiders were significant, ranging from 26 percent for hens with broods to 52 percent for postnesting females with out young. Birds usually were seen loafing on shore. Of the 36 observations of adult spectacled eiders throughout their summer residence, 33 (92 percent) were on Class IV wetlands. Birds were swimming or loafing but not feeding.

Oldsquaws preferred ($P<0.01$) Deep-Arctophila wetlands prior to and during nesting (Table 9). Highest densities of pairs occurred on portions of drained lakes possessing a network of second generation Class IV ponds. A 50 ha complex of basins was used each year by four pairs; that density extrapolates to 16 birds per km^2 compared to mean peak densities of 4.3 to

Table 10. Foods consumed by loons and geese at wetlands. Foods of loons were identified from esophagus-proventriculus-gizzard contents, and foods of geese were determined by observing individuals feeding and examining feeding sites

Wetland class	Species	Feeding site	No. of birds	Ages of birds	Food items
Deep-*Arctophila* (IV)	Arctic Loon	Water	1	Adult	Notostraca (tadpole shrimp) Trichoptera (caddisfly larvae) Anostraca (fairy shrimp) Cladocera (water fleas)
	Arctic Loon	Water	2	2-3 wk	Notostraca (tadpole shrimp)
Deep-open (V)	Canada Goose	Shore	120	Adults and young	*Carex aquatilis* and *Eriophorum angustifolium*
	White-fronted Goose	Shore	50	Adults and young	*C. aquatilis* and *E. angustifolium*
Seasonal-mosaic (VI)	Arctic Loon	Water	1	2 days	Trichoptera (caddisfly larvae)
	Red-throated Loon	Water[a]	2	1-3 days	*Boreogadus saida* (arctic cod)
Coastal Wetland (VII)	Black Brant	Water and Shore	100's	Adults and young	*C. subspathacea* and *Puccinelia phryganodes*

[a]Young loons were fed fish captured at sea by adult loons.

5.1 birds per km^2 for the entire study area. Oldsquaws exhibit territoriality; hence, one factor influencing high densities may be ridges separating ponds which provide visual isolation from neighbors. Oldsquaws were often seen diving in Class IV wetlands, presumably to feed.

Ten of the 11 black brant nests and two of the three spectacled eider nests were found at Deep-Arctophila wetlands. Nests were placed on tundra or islets next to an abrupt shore. All nest-ponds were second generation basins lying in the same first generation drained basin.

Deep-open Lakes (Class V)

Deep-open lakes were used most frequently by waterbirds in July and August when the lakes were icefree. Principal use in June was by oldsquaws loafing on banks or ice and diving in the moat of water near shore.

Use of Class V lakes by arctic loons was significant ($P<0.05$) following nesting. Birds observed were adults, usually in small flocks, that presumably were unsuccessful at nesting or brood-rearing.

Deep-open lakes and adjacent tundra were used by Canada geese and white-fronted geese during their wing-molt in the last half of July and during August. In 1973, a flock of Canada geese, numbering approximately 100 flightless adults and 20 goslings, resided in the vicinity of two large lakes (175 ha and 200 ha) located 10 km to 15 km southeast of Point Storkersen. Groups of white-fronted geese, containing mostly parents and broods, were counted in the study area on 21 occasions, and, of these, 19 involved groups on or near a 60 ha Class V lake. Similar sized flocks of white-fronted geese were seen on other Deep-open lakes in the Prudhoe Bay area. While undisturbed, Canada geese and white-fronted geese rested or grazed

(Table 10) in upland tundra near lake shores. Flightless geese responded to disturbance from men on the ground or low flying aircraft by moving offshore to open water or by moving overland to another lake.

Oldsquaws, predominantly females, gathered on Deep-open lakes in the last week of July or the first week of August to pass their flightless stage. The oldsquaw population at this time was comprised of about 95 percent females. Eighty-five percent of the birds counted after the nesting period (Table 9) were on the largest lake (60 ha) in the study area. Moreover, all flightless oldsquaws in the study area used this lake. Peak use of the lake occurred in mid-August; numbers varied from 45 in 1972 to 70 in 1973.

Seasonal-mosaic Lakes (Class VI)

Loons

Frequencies that arctic and red-throated loons used Seasonal-mosaic lakes were most significant during the period prior to nesting (Table 9). Presumably, the higher frequencies in early summer resulted because loons were able to use the extensive areas of shallow water before deeper wetlands thawed. Both species used Class VI lakes for nesting and brood-rearing, but only use by red-throated loons was significant ($P<0.01$). Pairs occupied isolated pools within basins and constructed nest platforms of dead vegetation.

Feeding activities of loons corresponded with activities at Class IV wetlands. Adult arctic loons fed themselves and their young on organisms captured in the lake, whereas adult red-throated loons fed at sea and brought fish back to their young (Table 10).

Waterfowl

Nonbreeding pintails preferred ($P<0.01$) Seasonal-mosaic lakes throughout their residence (Table 9). Greatest use by pintails occurred during the wing-molt in July; 92 percent of the flightless pintails counted were in the largest (85 ha) Class VI lake near Point Storkersen. Pintails usually were well hidden in the cover created by stands of Arctophila fulva and Carex aquatilis. Based on birds observed during June (Figure 6), feeding is a major activity of pintails on Seasonal-mosaic lakes.

King eiders, usually paired, gathered in large numbers on Class VI lakes during the first half of June; as a result, frequency of use by king eiders was highly significant ($P<0.05$) prior to nesting (Table 9). Shallow areas of Class VI lakes frequently were used for feeding by King eiders (Figure 6). As thaw progressed, king eider pairs dispersed to wetlands of other classes, especially Deep-Arctophila wetlands.

In 1973, a pair of whistling swans nested and raised young in a Class VI basin. The nest was placed on a detritus platform surrounded by shallow water and emergents. The adults and cygnets were able to remain concealed in stands of Arctophila fulva until I approached to within a few meters of them.

Other waterfowl, especially visitors (Table 5), often were seen in Seasonal-mosaic lakes during June.

Coastal Wetlands (Class VII)

Coastal Wetlands were dominantly used by migrating black brant. During the first half of June, flocks of up to 100 brant migrated east along the coast and often used open water and snowfree shores of Class VII wet-

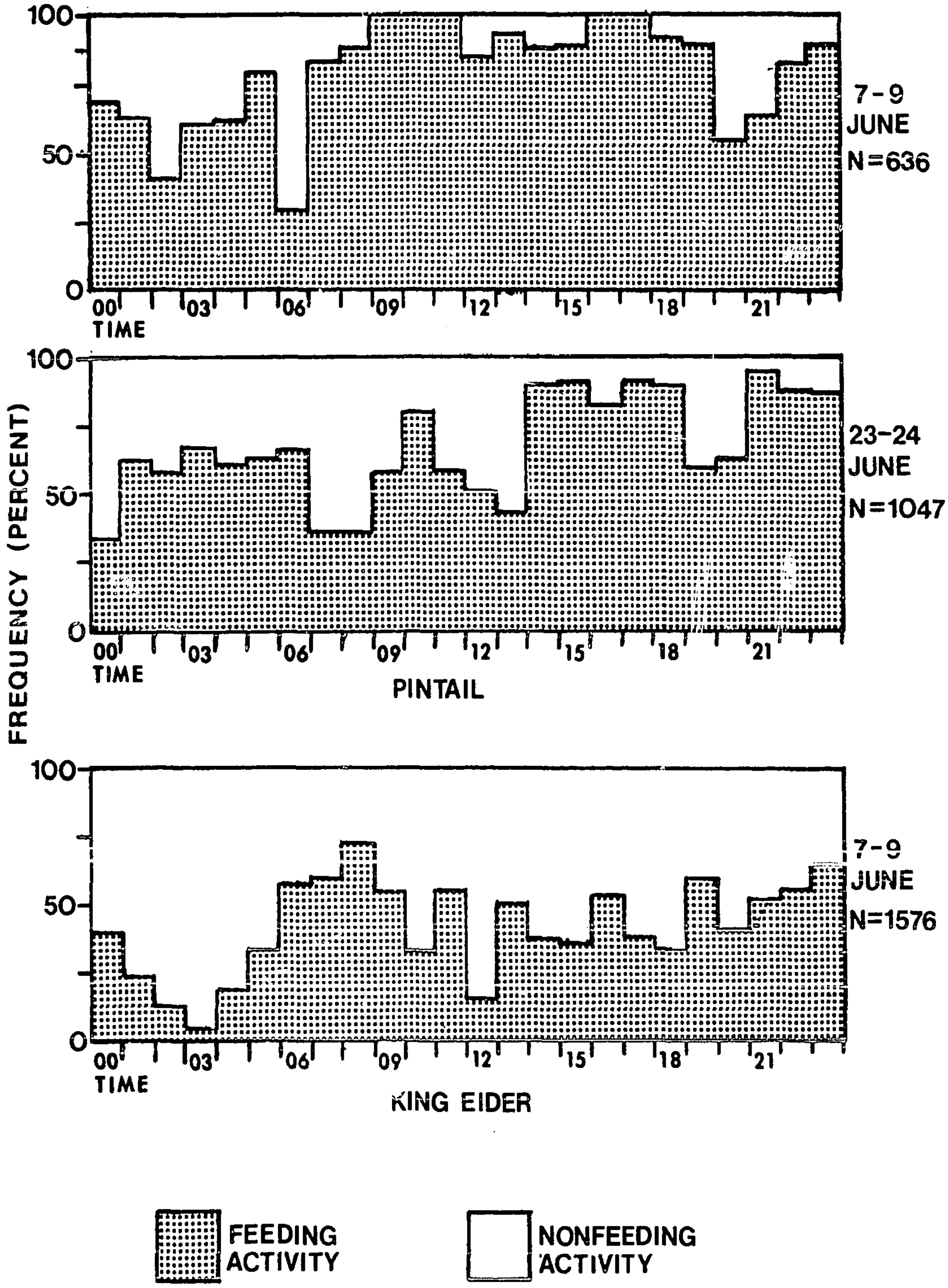

Figure 6. Diurnal activities of pintails and king eiders on a Seasonal-mosaic lake. (N = number of observations of birds)

lands. Fall migration of brant did not pass Point Storkersen until after field seasons terminated on 14 August. However, during a visit to the study area on 2 September, 1973, I saw three flocks of 100 to 350 birds flying west. The largest flock stopped to rest and feed along shores of Coastal Wetlands. Carex subspathacea and Puccinellia phryganodes appeared to be principal foods of migrating black brant (Table 10).

Black brant families moved to coastal habitats within a few days after young hatched. Two families were observed from 11 July to 17 July, 1973, in a complex of Coastal Wetlands. The birds fed (Table 10) and rested on flats between ponds and on a point jutting into the sea.

Beaded Streams (Class VIII)

All species of loons and ducks that resided in the study area occasionally were seen on Beaded Streams (Table 9). Pintails and eiders used portions of the flood plain temporarily inundated by water during spring breakup. Oldsquaw pairs established territories on segments of the stream during the prenesting and nesting periods.

DISCUSSION

Oil development will affect the wetlands-waterbird community mainly through oil contamination and disturbance to birds from men or machines. Although the impact of development has been assessed mainly along the proposed route of the trans-Alaska pipeline, oil spills and disturbances probably will be more frequent in the oil fields where pipeline systems and roads will link oil wells to the main pipeline. Oil spills in this region undoubtedly will be most dramatic in stream drainages, but wherever drainage is poor, local bird populations may be harmed if oil enters wetlands intensively used by birds. Such areas will be especially susceptible to oil pollution during spring thaw when melt water flows rapidly and extensively over the impermeable tundra surface.

Damage to waterbird populations from oil-related activities will be most serious on wetlands limited in numbers but intensively used by birds. Based on evidence from this study, such wetlands include Deep-*Arctophila* ponds and lakes (Class IV), Deep-open lakes (Class V), Seasonal-mosaic lakes (Class VI), and Coastal Wetlands (Class VII). Wetlands in other classes are more abundant and less intensively used by loons and waterfowl; however, their value to other waterbirds is yet to be evaluated.

RECOMMENDATIONS

The following recommendations could minimize conflicts between waterbirds and petroleum development in the Prudhoe Bay oil fields: (1) pipelines, pump stations, oil wells, and other facilities containing oil should be restricted to sites where leaking oil cannot enter waters or watersheds of wetlands, especially wetlands in Classes IV through VIII; (2) where facilities must be in watersheds, regular inspection is essential and contingency plans should be ready for rapid containment of oil; (3) other pollutants such as drilling mud, solid wastes, and fluid wastes should not be discarded into wetlands; (4) during 15 May to 1 October, all activities should be prohibited within 1 km of wetlands in Classes IV through VII; (5) ... roads and pipelines should be constructed so that a minimum number of ...ss IV-VIII wetlands are affected; (6) activities that could drain wetlands should be prohibited; and (7) low-level aircraft activity should be minimized.

Specific wetlands of unique importance to birds and extensive blocks of coastal plain containing a diversity of wetlands should be protected from all forms of development. Wetlands of outstanding importance to birds need to be identified and preserved. For example, lakes and tundra between Cape Halkett and Teshekpuk Lake on the Western Coastal Plain are major concentration areas for several species of geese during their wing-molt. If protected, units of coastal plain such as the Point Storkersen study area could serve as control areas for measuring the impact of industrial activities in development areas. Moreover, refuges would provide undisturbed plant and animal communities for scientific investigations.

Future studies relevant to understanding relationships between birds, wetlands, and petroleum development should include studies of: (1) the use of classes of wetlands by phalaropes and other species of shorebirds; (2) techniques for rapidly and accurately appraising wetlands in large areas of coastal plain; (3) the accuracy of predicting the structure of waterbird populations on the basis of wetlands inventories; (4) the capacity of melt water to transport oil over the impermeable tundra surface during spring thaw; and (5) the toxicity of oil to aquatic food resources of birds.

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